

NASA Exploration Systems Mission Directorate Request for Comments on Draft Rules for Possible Centennial Challenges Competitions

GENERAL INFORMATION:

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General Information

This Request for Comments (RFC) is being processed out of the NASA Office of Exploration Systems, Brant Sponberg, Mail Suite 2M13, 300 E Street SW, Washington DC 20546, Tel: (202) 358-1160.

External organizations and individuals are sought to provide input and comments on the proposed set of rules for multiple competitions (included as appendices to this RFC) including:

- Appendix 1. The Fuel Depot Demonstration Challenge
- Appendix 2. The Human Lunar All Terrain Vehicle Challenge
- Appendix 3. The Low-Cost Space Pressure Suit Challenge
- Appendix 4. The Lunar Night Power Source Challenge
- Appendix 5. The Micro Reentry Vehicle Challenge
- Appendix 6. The Station-Keeping Solar Sail Challenge

The input and comments received from this RFC will be used by NASA to modify the draft rules of these competitions and validate the proposed parameters and technology goals. Final rules and purse amounts will be determined pending future organizational, programmatic, and budget decisions.

Respondents are requested to respond to as many of the RFC elements below for each competition as they wish.

NASA is planning to administer these competitions through one or more third-party organizations that will be responsible for finalizing the rules. Although no organizations have been selected to run any of these competitions, this RFC is being initiated to begin the process of rules development in the interest of time.

Centennial Challenges Overview

NASA Centennial Challenges was established to conduct prize competitions in support of the Vision for Space Exploration and ongoing NASA programs. Centennial Challenges is modeled on past prize competitions, including the 18th century British Longitude Prize; early 20th century aviation competitions, such as the Orteig Prize won by Charles Lindbergh; the Defense Advanced Research Projects Agency (DARPA) Grand Challenge; and the privately funded Ansari X PRIZE. By making awards based on actual achievements instead of proposals, Centennial Challenges seeks novel and lower-cost solutions to engineering obstacles in civil space and aeronautics from new sources of innovation in industry, academia, and the public.

For some of the Challenges listed below, NASA hopes to offer cash purses ranging into the millions of dollars to the winners.

Overview of the Fuel Depot Demonstration Challenge

The purpose of the Fuel Depot Demonstration Challenge is to promote the development of cryogenic fluid management technologies that have wide application in the space community. The development of a high-efficiency cryogenic fluid storage and transfer system could significantly lower the cost and complexity of space exploration missions and enable new commercial space markets.

The Fuel Depot Demonstration Challenge purse of \$5,000,000 will be awarded to the first team that could build, launch, and demonstrate a subscale liquid hydrogen and liquid oxygen storage or production facility system in Earth orbit.

Please refer to Appendix 1 for the complete set of draft rules.

Overview of the Human Lunar All Terrain Vehicle Challenge

The Human Lunar All Terrain Vehicle (ATV) Challenge is designed to advance development of a human-operated ATV that can traverse the lunar terrain for scientific exploration and general astronaut mobility. This competition promotes the development of a functional prototype astronaut vehicle that is safe, agile, easy to stow and use, efficient and reliable.

Teams will compete by driving their vehicles over a course that tests the capabilities of each vehicle. A \$1,000,000 purse will be awarded to the winning team.

Please refer to Appendix 2 for the complete set of draft rules.

Overview of the Low-Cost Space Pressure Suit Challenge

The Low-Cost Space Pressure Suit Challenge is designed to broaden the industrial base for human space flight and stimulate the development of commercially available space suits for passengers of future commercial space vehicles. Future suits must be designed to be worn by passengers for the duration of a space flight and to protect space passengers in the case of rapid cabin depressurization. The suit should have features that support the wearer's space flight experience, such as minimizing restrictions to mobility when un-pressurized and allowing the wearer to have their head uncovered when un-pressurized. This competition promotes the development of a suborbital suit that is safe and cost effective for both the passenger and the space flight provider.

The Low-Cost Space Pressure Suit Challenge is a first to complete competition with a purse of \$500,000. To win this Challenge, a Team must be the first to demonstrate the ability of their suit to meet design and test requirements, including a depressurization test on an instrumented mannequin in a test chamber. To ensure cost effectiveness of the suit, a Team must sell a certain number of their suits in an open market.

Please refer to Appendix 3 for the complete set of draft rules.

Overview of the Lunar Night Power Source Challenge

The Lunar Night Power Source Challenge is designed to promote the development of power systems and technologies that can operate for long periods in a harsh environment. Historically, planetary surface power technologies have relied primarily upon radioisotopes or available solar energy, providing limited options for operating during planetary nights. The specific objective of this Challenge is to develop rechargeable power system technologies that could support a rover during the lunar night and that have other potential space- and Earth-based applications.

To win the Lunar Night Power Source Challenge and the \$500,000 purse, a Team must be the first to demonstrate a rechargeable power source that provides power over a period of one lunar night (approximately 14 days) while meeting volume and heat requirements.

Please refer to Appendix 4 for the complete set of draft rules.

Overview of the Micro Reentry Vehicle Challenge

The Micro Reentry Vehicle Challenge is designed to accelerate technology development that could lead to a routine method to return viable samples from orbital research platforms to the Earth's surface. This capability would have an important impact on NASA and commercial space-based research.

To win the Micro Reentry Vehicle Challenge purse of \$2,000,000, a reentry vehicle must return six of twelve common hen eggs safely to Earth from low Earth orbit without damage.

Please refer to Appendix 5 for the complete set of draft rules.

Overview of the Station-Keeping Solar Sail Challenge

The Station-Keeping Solar Sail Challenge is designed to promote the development of solar sail technology and the commercial services that may result from the ability to operate in novel orbits such as artificial Lagrange points.

The Station-Keeping Solar Sail Challenge has two prizes. To win Prize One and the \$2,500,000 purse, a Team must be the first to deploy a solar Sailcraft, demonstrate a resultant trajectory acceleration change of at least .05 millimeters per second squared, and fly along a trajectory that will pass through a defined target located at the first Sun-Earth Lagrange point (L1). To win Prize Two and the \$2,500,000 purse, a Team must enter a defined region above or below the ecliptic plane at L1 and remain there for 90 consecutive days.

Please refer to Appendix 6 for the complete set of draft rules.

Submission Details

NASA is interested in receiving comments, suggestions, ideas, or other forms of feedback regarding the draft rules in each of the appendices to this RFC. It is important to provide rationales to support your inputs. NASA is especially interested in comments from potential competitors but other parties are invited to comment as well.

Questions whose answers are characteristic of the submissions we would expect in response to this RFC for each competition are listed at the end of each of this document's appendices. It is not an exhaustive list of questions to be answered, but only a sampling to stimulate your responses.

Multiple responses to this RFC from the same organization or individual are welcome.

Electronic submission of responses to this RFC is encouraged. Feedback may be included in the body of an email or as an attachment to an email.

The feedback may be in any form or format. For example, you may copy the text of the rules into a MS Word document and provide comments using the "Track Changes" function of the application if you so desire.

In each of the appendices, the term "Team" is used to denote the individual or organization that is participating in the competition to win the purse.

The following organizational/individual contact information should be included on any submission in response to this RFC:

- Organization and/or Individual Name

- Complete Mailing Address
- Telephone Number(s)
- Email Address(es)
- Reference document ESMD-CC-0601

Future Use of Responses

This RFC is for information and planning purposes. No procurement is planned as a direct result of this RFC. This is not to be construed as a commitment by the Government nor will the Government pay for information solicited.

Respondents will not be notified of the results of the evaluation. Parties proposing concepts of interest may be invited to submit more detailed information or to discuss their concepts further.

Information submitted as a direct response to this RFC will not be made publicly available, but may be used, in whole or in part and without credit or reference to the source of the material, in documents that will be made publicly available at a future date.

It should be noted that this is not a request for prize ideas unrelated to the subjects of this RFC. Any unrelated prize ideas should be submitted through the Centennial Challenges web site (www.centennialchallenges.nasa.gov) or via email sent to ccideas@nasa.gov.

Technical questions regarding this RFC should be directed to Ken Davidian, 202-358-0748 or kdavidian@nasa.gov.

All submissions must be received by March 27, 2006 by 5:00 P.M. EDT to Ken Davidian at kdavidian@nasa.gov and should include the reference document number ESMD-CC-0601.

Appendix 1. The Fuel Depot Demonstration Challenge - Draft Rules

Overview

The purpose of the Fuel Depot Demonstration Challenge is to promote the development of cryogenic fluid management technologies that have wide application in the space community. The development of a high-efficiency cryogenic fluid storage and transfer system could significantly lower the cost and complexity of space exploration missions and enable new commercial space markets.

The Fuel Depot Demonstration Challenge purse of \$5,000,000 will be awarded to the first team that could build, launch, and demonstrate a subscale liquid hydrogen and liquid oxygen storage or production facility system in Earth orbit.

Definitions

a. Advance Notification Information - In accordance with the Advance Notification Period Terms, Team will:

- (1) Provide to Org the location and the start date of the Competition Attempt.
- (2) Provide to Org a detailed description (and possible demonstration) of their System's safe design and operation.
- (3) Provide to Org a detailed description of, and receive written acceptance of, the data acquisition methods employed to verify and validate System performance in order to win the Challenge. If Org does not approve the proposed data acquisition methods, Org will identify specific shortcomings and provide this information to the Team. It will then be the responsibility of Team to resubmit a new data acquisition procedure that addresses the shortcomings of their previous submission.
- (4) Notify Org of any known Competition Attempt delays at its earliest opportunity. If, in the opinion of Org, Team provides serial notices of delays for the purpose of gaining competitive advantage, the Team will be required to reinitiate the advance notification process.

b. Advance Notification Period Terms - At least 60 days prior to any Competition Attempt:

- (1) Team must be officially registered and provide their intent to compete in the Challenge by providing design compliance and operational safety information to Org.
- (2) Team will provide Org with all Advance Notification Information.
- (3) Team will show or demonstrate compliance with all Minimum Design Requirements.

c. Challenge - The Fuel Depot Demonstration Challenge.

d. Competition Attempt – The operation by Team of the System under Test Conditions for the Test Duration with the intention of winning the Challenge. The Competition Attempt will take place in accordance with the Advance Notification Period Terms and consist of the following events:

(1) Put a tank (or tanks) containing the Minimum Mass of the Propellants in LEO. (NOTE: the Propellants can be delivered to LEO, generated while in LEO, or anything else in between.)

(2) Store the Propellants in the tank (or tanks) for the Storage Duration while in LEO.

(4) At least two weeks before the end of the Storage Duration in LEO, the Propellant Minimum Mass should be liquefied and stored in separate tanks as saturated liquids at 16 +/- 0.5 pounds per square inch (absolute) for the remainder of the Storage Duration.

e. Deadline - January 1, 2012 (local date and time in Washington, D.C., U.S.A.). The Deadline may be extended at the sole discretion of NASA.

f. Low Earth Orbit – Any orbit around the Earth above the altitude of 200 kilometers, aka LEO.

g. Minimum Mass - At least 20 kg of liquid hydrogen and at least 120 kg of liquid oxygen.

h. Minimum Design Requirements – The System shall:

(1) Be capable of storing the Minimum Mass of both Propellants in separate tanks for the Storage Duration.

(2) Survive an Earth-to-orbit launch environment.

i. Org - Organization that is administering and executing the Challenge.

j. Propellants - Hydrogen and oxygen.

k. Storage Duration - 120 days.

l. System - All equipment (including all hardware, software, power system, thermal cooling system, etc.) that is part of the Propellant production and storage system entered by Team to compete in the Challenge.

Rules

a. Technical specifications not already covered in this Agreement about any Challenge details will be provided by Org to Team at the time of registration. These technical specifications may be subject to future updates by Org at its sole discretion.

b. Before the Competition Attempt, Team shall comply with the Advance Notification Period Terms.

c. For the Competition Attempt, Team shall provide or make arrangements for the use of the System and all the other necessary launch vehicles, test facilities, equipment, fluids, and consumables that will prove the performance of their System.

d. The System must be launched into Low Earth Orbit and successfully perform and complete all the Functional Tasks.

e. If Team successfully completes the Competition Attempt before the Deadline, the Team shall be deemed the winner of the Challenge and receive the prize purse of \$5,000,000 (five million U.S. dollars).

Questions for Consideration by Respondent

- Are any of the definitions given missing, over-specifying, or incorrectly specifying important qualitative and quantitative parameters? (E.g., the maximum allowable mass is too low, etc.) If so, what should the proper parameter specification be and why?
- Are there any logistical or practical situations that have been overlooked? (E.g., considerations of safety, validation, operation of the competition event, etc.) If so, what situation has been overlooked and how should it be handled?
- Is the prize purse adequately sized? Why or why not?
- Are there alternative ideas for conducting the competition, or scoring and awarding the prizes for the competition? If so, what are your proposed ideas and why?

Appendix 2. The Human Lunar All Terrain Vehicle Challenge - Draft Rules

Overview

The Human Lunar All Terrain Vehicle (ATV) Challenge is designed to advance development of a human-operated ATV that can traverse the lunar terrain for scientific exploration and general astronaut mobility. This competition promotes the development of a functional prototype astronaut vehicle that is safe, agile, easy to stow and use, efficient and reliable.

Teams will compete by driving their vehicles over a course that tests the capabilities of each vehicle. A \$1,000,000 purse will be awarded to the winning team.

Definitions

a. Advance Notification Period Terms - At least 90 days prior to the Competition Event, Team must be officially registered and provide their intent to compete in the Challenge at the Competition Event by providing and possibly demonstrating design compliance and operational safety information to Org.

b. Challenge - The Human Lunar All Terrain Vehicle (ATV) Challenge.

c. Competition Attempt - The operation by Team of their Vehicle in the Heats. Judges may stop any Competition Attempt to ensure the safety and integrity of the Challenge.

d. Crew - People driving or riding in/on the Vehicle.

e. Final Heat – The competition in which Vehicles must meet Final Heat Requirements to be eligible to win the Challenge.

f. Final Heat Requirements - The Team shall operate the Vehicle for a minimum average speed of 10 kilometers per hour for a minimum distance of 10 kilometers.

g. Heats – Two rounds of competitions, the Qualifying Heat and the Final Heat.

h. Minimum Design Requirements - The Vehicle shall:

(1) Have a mass not to exceed 300 kilograms, not including Crew and Payload.

(2) Have the capability to safely and comfortably carry a minimum of two Crew and 2 cubic meters of Payload.

(3) Have the capability to safely and comfortably carry a combination of Crew and Payload with a minimum mass of 500 kilograms.

(4) Be able to drive through a track width of 3 meters.

(5) Be able to meet the Unstowing Requirement.

(6) Have a compact storage and transport volume not to exceed 2.5 cubic meters.

(7) Use technology that is consistent with the lunar environment, such as a power system that does not use atmospheric reactants.

(8) Not utilize external power sources (e.g., solar power).

i. Operational Requirements – At all times during both Qualifying and Final Heats:

(1) At least one Crew member must operate the Vehicle at all times.

(2) At least two Crew and 2 cubic meters of Payload shall be carried by the Vehicle.

(3) At least 500 kilograms of combined Crew and Payload weight shall be carried by the Vehicle.

(4) The Vehicle shall stay on the prescribed route of the Test Course during all phases of the Heats.

(5) Crew may be switched at any time for safety or health reasons. Vehicle must be stationary while Crew is being switched out.

(6) Nothing may be jettisoned from the Vehicle.

(7) No repairs, change-out of equipment, recharging, or replacement of consumables may be performed on the Vehicle during a Heat.

(8) The Vehicle shall only be handled by the two Crew in/on the Vehicle.

(9) There shall be no remote operation of the Vehicle.

j. Org - Organization that is administering and executing the Challenge.

k. Payload – Representative cargo mass carried by the Vehicle but not an integral part of the Vehicle.

l. Qualifying Heat - The competition in which Vehicles must meet Qualifying Heat Requirements before advancing to the Final Heat.

m. Qualifying Heat Requirements - The Team shall:

(1) Meet the Unstowing Requirement.

(2) Operate the Vehicle on the Test Course at a minimum average speed of 10 kilometers per hour for a minimum distance of 2 kilometers.

n. Test Course - The location of the Heats, to be identified by Org, that will have at least the following conditions: rough and rocky terrain, 30.48 cm (1 foot) maximum obstacle height that the vehicle must be able to drive over, craters, up and down slopes of up to 20 degrees, dusty and sandy conditions, and curves with a turning radius of no less than 3 meters.

o. Unstowing Requirement – The capability of the Vehicle to be converted by a maximum of two people from the configuration for compact storage and transport to the configuration for normal surface operations in a maximum of 10 minutes.

p. Vehicle - Hardware and software designed, built, procured or otherwise obtained for use by the Team whose operation is intended to win the Challenge, including any or all stages or parts used during any phase of operation.

Rules

a. Technical specifications not already covered in this Agreement about any Challenge details will be provided by Org to Team at the time of registration. These technical specifications may be subject to future updates by Org at its sole discretion.

b. Before the Competition Event, Team shall comply with the Advance Notification Period Terms.

c. Vehicle must meet all Minimum Design Requirements, Operational Requirements and safety inspection.

d. Each Team will participate in a Qualifying Heat.

e. Teams that satisfy the Qualifying Heat Requirements will be eligible to make a Competition Attempt in the Final Heat.

f. The Team that satisfies the Final Heat Requirements in the fastest time will win the purse of \$1,000,000 (one million U.S. dollars).

Questions for Consideration by Respondent

- Are any of the definitions given missing, over-specifying, or incorrectly specifying important qualitative and quantitative parameters? (E.g., the maximum allowable mass is too low, etc.) If so, what should the proper parameter specification be and why?
- Are there any logistical or practical situations that have been overlooked? (E.g., considerations of safety, validation, operation of the competition event, etc.) If so, what situation has been overlooked and how should it be handled?
- Is the prize purse adequately sized? Why or why not?

- Are there alternative ideas for conducting the competition, or scoring and awarding the prizes for the competition? If so, what are your proposed ideas and why?

Appendix 3. Low-Cost Space Pressure Suit Challenge – Draft Rules

Overview

The Low-Cost Space Pressure Suit Challenge is designed to broaden the industrial base for human space flight and stimulate the development of commercially available space suits for passengers of future commercial space vehicles. Future suits must be designed to be worn by passengers for the duration of a space flight and to protect space passengers in the case of rapid cabin depressurization. The suit should have features that support the wearer's space flight experience, such as minimizing restrictions to mobility when un-pressurized and allowing the wearer to have their head uncovered when un-pressurized. This competition promotes the development of a suborbital suit that is safe and cost effective for both the passenger and the space flight provider.

The Low-Cost Space Pressure Suit Challenge is a first to complete competition with a purse of \$500,000. To win this Challenge, a Team must be the first to demonstrate the ability of their suit to meet design and test requirements, including a depressurization test on an instrumented mannequin in a test chamber. To ensure cost effectiveness of the suit, a Team must sell a certain number of their suits in an open market.

Definitions

a. Advance Notification Information - In accordance with the Advance Notification Period Terms, Team will:

- (1) Provide to Org the location and the start date of the Depressurization Test.
- (2) Team must provide to Org detailed documentation (and possible demonstration) of the Suit's compliance with the Design and Operational Requirements.
- (3) Provide to Org a detailed description of the Test Procedure, including data acquisition methods employed to verify and validate the Suit performance in the Depressurization Test, and receive written acceptance of the Test Procedure as an approved method of validation and verification to win the Challenge. If Org does not approve the proposed Test Procedure, Org will identify specific shortcomings and provide this information to the Team. It will then be the responsibility of Team to resubmit a new Test Procedure that addresses the shortcomings of the previous submission as identified by Org.
- (4) Notify Org of any known Depressurization Test delays at its earliest opportunity. If, in the opinion of Org, Team provides serial notices of delays for the purpose of gaining competitive advantage, the Team will be required to reinitiate the advance notification process.

b. Advance Notification Period Terms - At least 60 days prior to the Depressurization Test:

- (1) Team must be officially registered.

(2) Team will provide Org with all Advance Notification Information.

c. Challenge - The Low-Cost Space Pressure Suit Challenge.

d. Depressurization Test – The test of the Suit on a Mannequin in a vacuum test chamber that will be conducted as follows:

(1) At the start of the test the Suit will be un-pressurized and in the normal flight configuration.

(2) Test Chamber pressure will be decreased from Vehicle Ambient Conditions to Vacuum in 3 seconds

e. Design and Operational Requirements – The Suit must meet the following requirements:

(1) The Suit must be designed to be worn by the Wearer during the full nominal Flight Profile.

(2) In an emergency situation, the Suit must be capable of operating in an un-pressurized Vehicle cabin while In-flight.

(3) Suit size, with options or adjustments that are available from the Team, must fit Wearers varying in size from a 5% American Female to 95% American Male.

(4) When un-pressurized, the Suit will not substantially restrict Wearer mobility and visibility.

(5) The un-pressurized Suit shall minimize Wearer heat/cold stress during the nominal Flight Profile. The Wearer's modeled body core temperature must not vary by more than +/- 1 deg C from its pre-suited value.

(6) In an emergency, when the Suit is pressurized, the Wearer's modeled core temperature shall not increase by more than 2 deg C with a resting metabolic rate.

(7) In the case of rapid Vehicle depressurization, the Suit must be designed to pressurize to a minimum of 9 psia (62.05 kPa) within 3 seconds.

(8) When pressurized, the Suit must maintain its basic un-pressurized size and shape to enable the Wearer to be restrained in a safe position for reentry or rescue.

(9) When pressurized, the Suit must have sufficient mobility so that Wearers can move to their designated safe position and secure themselves as required for reentry.

(10) The external Suit material must meet federal regulations and industry standards for flammability in relevant environments.

f. Flight Profile – The following flight phases are assumed for the purpose of this Challenge.

(1) Pre-Flight: Suited pre-launch activities that last 90 minutes.

(2) In-flight: 60 minutes launch-to-landing, to a minimum altitude of 62.12 miles (100 kilometers).

(3) Post-Flight: Suited post-landing activities that last 60 minutes.

g. Mannequin – A physical, nonhuman model of a human used to test the Suit.

h. Market Test Success Criteria- To ensure the commercial viability and cost effectiveness of the Suit a Team must sell at least ten (10) of the Suits in an Open Market. In the case of a lease, the lessee must fly at least ten (10) of the Suits.

i. Open Market - A market in which the product is widely accessible to all consumers at the same price.

j. Org – Organization that is administering the Challenge.

k. Suit – The Space Pressure Suit provided by the Team to be submitted to the Depressurization and Market Tests.

l. Test Procedure – The facilities, equipment, data acquisition instruments, procedures, conditions, etc., which will be used in the Depressurization Test.

m. Vacuum – The environment that the Suit experiences at depressurization, which is equivalent to an atmospheric pressure at an altitude of at least 60,000 feet (18,288 meters) mean sea level at standard atmospheric conditions.

n. Vehicle – A spacecraft that transports humans.

o. Vehicle Ambient Conditions - The Suit test environment that simulates a Vehicle with a pressure of no less than 9 psia (62.05 kPa) with no less than 3.06 psia (21.0 kPa) partial pressure O₂.

p. Wearer – An individual wearing the Suit.

Rules

a. Technical specifications not already covered in this Agreement about the Suit, the Depressurization Test, and any other Challenge details will be provided by Org to the Team at the time of registration. These technical specifications may be subject to future updates by Org at its sole discretion.

- b. Before the Depressurization Test, Team shall comply with the Advance Notification Period Terms.
- c. For the Depressurization Test, Team shall provide or make arrangements for the use of the Suit and all the other necessary test facilities, equipment, fluids, and consumables that will prove the performance of their Suit.
- d. The Suit must successfully complete the Depressurization Test by accomplishing the following:
- (1) The Suit must pressurize to 9 psia (62.05 kPa) within 3 seconds of the test chamber achieving Vacuum.
 - (2) The Suit must maintain a safe level of pressurization for at least 1 hour in Vacuum conditions, without any uncontrolled leaks.
- e. The Team must satisfy the Market Test Success Criteria.
- f. The first Team that satisfies all rule requirements will win a prize of five hundred thousand U.S. dollars (500,000 USD).
- g. The Challenge is open until November 1, 2010.

Questions for Consideration by Respondent

- Are any of the definitions given missing, over-specifying, or incorrectly specifying important qualitative and quantitative parameters? (e.g., pressures are inappropriate, etc.) If so, what should the proper parameter specification be and why?
- Are there any logistical or practical situations that have been overlooked? (E.g., considerations of safety, validation, operation of the competition event, etc.) If so, what situation has been overlooked and how should it be handled?
- Is the prize purse adequately sized? What is the rationale?
- Are there alternative ideas for conducting the competition, or scoring and awarding the prizes for the competition? If so, what are your proposed ideas and why?

Appendix 4. The Lunar Night Power Source Challenge – Draft Rules

Overview

The Lunar Night Power Source Challenge is designed to promote the development of power systems and technologies that can operate for long periods in a harsh environment. Historically, planetary surface power technologies have relied primarily upon radioisotopes or available solar energy, providing limited options for operating during planetary nights. The specific objective of this Challenge is to develop rechargeable power system technologies that could support a rover during the lunar night and that have other potential space- and Earth-based applications.

To win the Lunar Night Power Source Challenge and the \$500,000 purse, a Team must be the first to demonstrate a rechargeable power source that provides power over a period of one lunar night (approximately 14 days) while meeting volume and heat requirements.

Definitions

a. Advance Notification Information - In accordance with the Advance Notification Period Terms, Team will:

- (1) Provide to Org the location and the start date of the Competition Attempt.
- (2) Provide to Org a detailed description (and possible demonstration) of their Power System's safe design and operation.
- (3) Provide to Org a detailed description of the Test Procedure, including data acquisition methods employed to verify and validate the Power System performance, and receive written acceptance of the Test Procedure as an approved method of validation and verification to win the Challenge. If Org does not approve the proposed Test Procedure, Org will identify specific shortcomings and provide this information to the Team. It will then be the responsibility of Team to resubmit a new Test Procedure that addresses the shortcomings of the previous submission as identified by Org.
- (4) Notify Org of any known Competition Attempt delays at its earliest opportunity. If, in the opinion of Org, Team provides serial notices of delays for the purpose of gaining competitive advantage, the Team will be required to reinitiate the advance notification process.

b. Advance Notification Period Terms - At least 60 days prior to any Competition Attempt:

- (1) Team must be officially registered and provide their intent to compete in the Challenge by providing design compliance and operational safety information to Org.
- (2) Team will provide Org with all Advance Notification Information.

- c. Autonomous Operation – No communication to or control of the Power System is allowed during the Competition Attempt except for turning the Power System on and off as needed to begin or end a test or for safety reasons.
- d. Calculated Specific Energy - A metric, with the unit of watt-hours/kilogram that defines how much energy is extracted from the Power System per unit mass. For the Challenge, Calculated Specific Energy is the electrical energy output by the Power System during the Thermal Environmental Test Duration, measured in watt-hours, divided by the mass of the Power System, in kilograms, while in the Charged State.
- e. Challenge – The Lunar Night Power Source Challenge.
- f. Charged State – The Power System state equivalent to being Recharged for one Lunar Day.
- g. Competition Attempt – The operation of the Power System with the objective of meeting all the requirements for winning the Challenge, including the following:
- (1) Power System must undergo a Leak Test in the Charged State.
 - (2) Power System must be brought to the Discharged State within 24 hours.
 - (3) Power System must be Recharged within one Lunar Day.
 - (4) Power System is weighed in the Charged State for the purpose of computing the Calculated Specific Energy.
 - (5) Power System must undergo the Thermal Environmental Test.
- h. Deadline - January 1, 2011 (local date and time in Washington, D.C., U.S.A.). The Deadline may be extended at the sole discretion of NASA.
- i. Discharged State – The Power System state equivalent to it having run for one Lunar Night.
- j. Leak Test – A vacuum chamber test to demonstrate that the Power System is fully-functional at low pressures and ambient temperatures, and does not leak any internally-contained fluids or gasses. The Leak Test duration will be between 8 and 48 hours.
- k. Lunar Day: Defined as one-half of the synodic period (708.14 hours), rounded to 350 hours for this Challenge.
- l. Lunar Night: Defined as one-half of the synodic period (708.14 hours), rounded to 350 hours for this Challenge.
- m. Org – The organization responsible for administering, executing, and judging the Challenge.

n. Power System – Any hardware and/or software, mechanical and/or electronic apparatuses, gases, fluids and/or consumables delivered by the Team to Org to compete in the Challenge. Power System does not include any cables and/or connectors that go from the Power System to any external equipment required to test or Recharge the Power System for the Challenge.

o. Power System Minimum Requirements - The Power System shall fulfill the following requirements:

(1) The Power System volume shall not exceed 0.027 cubic meters.

(2) The Power System shall be capable of transitioning from the Charged State to the Discharged State without the use, change-out, or reloading of additional power sources, thermal control systems, materials, or consumables.

(3) The Power System shall be designed to function autonomously in vacuum conditions and at temperatures of -40°C ($\pm 5^{\circ}\text{C}$).

(4) The Power System shall not leak any internally-contained fluids or gases.

(5) The Power System Calculated Specific Energy shall equal or exceed 400 watt-hours/kilogram.

(6) The Power System shall supply power at the Standard Voltage to the Test Load during the Thermal Environment Test.

(7) No alterations to the Power System, including change-out or replacement of hardware and/or software, mechanical and/or electronic apparatuses, gases, fluids and/or consumables is permitted at any time during the Competition Attempt.

p. Purse – Five hundred thousand U.S. dollars (500,000 USD).

q. Recharge – Conditioning the Power System to the Charged State through the use of a system provided by the Team that provides Standard Voltage. Recharge cannot be achieved through change-out or replacement of Power System hardware and/or software, mechanical and/or electronic apparatuses, gases, fluids and/or consumables.

r. Standard Voltage - A constant 30 Volts DC, ± 6 Volts DC.

s. Test Load – A mechanical or electronic system that imposes a power load profile on the Power System. The power load profiles will have a period of 24 hours to typify a Lunar Night work cycle for a notional lunar rover, and will be determined by Org. Although the power load profile from one 24-hour period to the next may or may not be the same, each power load cycle will draw 600 watt-hours (17 watts of power for a total of 1.8 hours, 25 watts of power for a total of 22 hours, and 97 watts of power in at least two spikes for a total of 0.2 hours).

t. Test Procedure - The facilities, equipment, data acquisition instruments, procedures, conditions, etc., under which the Cryo-System will be tested to verify it meets all the Minimum Requirements.

u. Thermal Environmental Test – Enclosure of the Power System in a chamber that exposes it to a thermal environment of -40°C (+/- 5°C) at one atmosphere of pressure for One Lunar Night. During this test, the Power System must successfully provide sufficient power to the Test Load.

v. Winning Team - Any Team that successfully meets or complies with all rules of the Challenge.

Rules

a. Technical specifications not already covered in this Agreement about the Power System and any other Challenge details will be provided by Org to the Team at the time of registration. These technical specifications may be subject to future updates by Org at its discretion.

b. Before the Competition Event, Team shall comply with the Advance Notification Period Terms.

c. For the Competition Attempt, Team shall provide or make arrangements for the use of the Power System and all the other necessary test facilities, equipment, fluids, and consumables that will prove the performance of their Power System.

d. Power System must meet or exceed all Power System Minimum Requirements.

e. The Power System must successfully complete the Competition Attempt.

f. The Power System cannot employ any fundamental processes that would not work in the lunar environment.

g. Org may make judgments regarding the Team's Competition Attempt failures and further attempts. If the Competition Attempt is interrupted due to circumstances not attributed to the Team, such as a test chamber failure, the Competition Attempt may be adjusted by Org at its discretion to compensate for the interruption.

h. Team will be judged the Winning Team if all the rules above are successfully completed.

i. The Winning Team will be awarded the Purse. If there is no Winning Team before the Deadline, the Purse will expire and will not be awarded.

Questions for Consideration by Respondent

- Are any of the definitions given missing, over-specifying, or incorrectly specifying important qualitative and quantitative parameters? (E.g., the maximum allowable mass is too low, etc.) If so, what should the proper parameter specification be and why?
- Are there any logistical or practical situations that have been overlooked? (E.g., considerations of safety, validation, operation of the competition event, etc.) If so, what situation has been overlooked and how should it be handled?
- Are there alternative ideas for conducting the competition, or scoring and awarding the prizes for the competition? If so, what are your proposed ideas and why?
- Is the prize purse adequately sized? Why or why not?

Appendix 5. Micro Reentry Vehicle Challenge - Draft Rules

Overview

The Micro Reentry Vehicle Challenge is designed to accelerate technology development that could lead to a routine method to return viable samples from orbital research platforms to the Earth's surface. This capability would have an important impact on NASA and commercial space-based research.

To win the Micro Reentry Vehicle Challenge purse of \$2,000,000, a reentry vehicle must return six of twelve common hen eggs safely to Earth from low Earth orbit without damage.

Definitions

a. Advance Notification Information - In accordance with the Advance Notification Period Terms, Team will:

(1) Provide to Org all pertinent information regarding the Reentry Attempt, including date, location, and mission profile.

(2) Provide to Org a detailed description (and possible demonstration) of their Vehicle's safe design and operation.

(3) Notify Org of any known Reentry Attempt delays at its earliest opportunity. If, in the opinion of Org, Team provides serial notices of delays for the purpose of gaining competitive advantage, the Team will be required to reinitiate the advance notification process.

b. Advance Notification Period Terms - At least 60 days prior to any Reentry Attempt:

(1) Team must be officially registered and provide their intent to compete in the Challenge by providing design compliance and operational safety information to Org.

(2) Team will provide Org with all Advance Notification Information.

c. Ambient Conditions – A temperature range between 40 to 50 degrees Fahrenheit, a relative humidity of 70 to 85 percent, a pressure range between one atmosphere +/- 1 pounds per square inch, and a linear or rotational acceleration (in or around any axis) of +/- 1 g.

d. Challenge – The Micro Reentry Vehicle Challenge.

e. Deadline - January 1, 2011 (local date and time in Washington, D.C., U.S.A.). The Deadline may be extended at the sole discretion of NASA.

f. Intact – Displaying no external or internal evidence of having been subjected to extreme temperatures, pressures, or accelerations, including cooking, cracking, or scrambling. The Payload yokes must be unbroken.

g. Minimum Design Requirements – The Vehicle design shall:

(1) Be designed to carry a total Payload mass of at least 1.5 kilograms.

(2) Have a Payload door or covering that can be opened easily and quickly to provide quick access to the Payload. The operation of removing the Payload from the Vehicle should take less than 5 minutes.

(3) Keep the Payload in Ambient Conditions and protect the Payload from temperature, pressure, and acceleration extremes.

(4) Have a backup flight termination system capable of eliminating any danger to the safety of property or the uninvolved public on the ground in case of a Vehicle system or event failure.

h. Org – The organization responsible for administering, executing, and judging the Challenge.

i. Payload – A dozen, USDA Grade AA, Jumbo, raw hens eggs, commonly found in any U.S. supermarket.

j. Purse - US\$2,000,000 (two million U.S. dollars).

k. Reentry Attempt – The operation of the Vehicle intended to meet all the requirements for winning the Challenge, including the following flight operations:

(1) Start from a low Earth orbit with a perigee altitude no less than 200 kilometers above the surface of the Earth.

(2) Reentry through the atmosphere.

(3) Land on the surface of the Earth within the Target Area.

l. Reentry Attempt Information - All information regarding the Flight Attempt, including dates, times, and locations of take-off, ejection location, reentry path, and landing.

m. Target Area - A circular area with a radius of 4 kilometers centered on the Target Point.

n. Target Point - The precise latitude and longitude location at which the Lander is trying to touchdown and come to rest. The Target Point will be selected relative to distinguishable features in the terrain.

o. Vehicle - The Team's Micro Reentry Vehicle. If one or more components of the Vehicle separate during the Reentry Attempt, the landing position determination will be made for only the Vehicle portion that houses the Payload.

Rules

- a. Technical specifications not already covered in this Agreement about any Challenge details will be provided by Org to Team at the time of registration. These technical specifications may be subject to future updates by Org at its sole discretion.
- b. Before the Competition Attempt, Team shall comply with the Advance Notification Period Terms.
- c. For the Competition Attempt, Team shall provide or make arrangements for the use of the Vehicle and all the other necessary launch vehicles, test facilities, equipment, fluids, and consumables that will prove the performance of their Vehicle.
- d. Vehicle must meet all Minimum Design Requirements.
- e. Team must comply with all local, state, and federal laws and regulations regarding the Reentry Attempt.
- f. The Vehicle must successfully perform the Reentry Attempt.
- g. If the Challenge judges deem circumstances to be unsafe for any reason at any time during the Reentry Attempt, they can initiate the Vehicle's flight termination system.
- h. Once the Vehicle has come to a complete stop at the end of the Reentry Attempt, the minimum distance between the Vehicle position on the ground and the Target Point will be measured to determine if any portion of the Vehicle is within the Target Area.
- i. If any part of the Vehicle is within the Target Area, the Payload will be removed from the Vehicle and inspected.
- j. If at least half of the Payload is deemed to be Intact by the Judges, the Reentry Attempt will be judged successful, and the Team will win the Challenge and be awarded the Purse.
- k. If no Team wins the Challenge before the Deadline, the Purse will expire and will not be awarded.

Questions for Consideration by RFI Respondent

- Are any of the definitions given missing, over-specifying, or incorrectly specifying important qualitative and quantitative parameters? (E.g., the maximum Vehicle mass is too low, etc.) If so, what should the proper parameter specification be and why?
- Are there any logistical or practical situations that have been overlooked? (E.g., considerations of safety, validation, operation of the competition event, etc.) If so, what situation has been overlooked and how should it be handled?
- Is the prize purse adequately sized? Why or why not?

- Are there alternative ideas for conducting the competition, or scoring and awarding the prizes for the competition? If so, what are your proposed ideas and why?

Appendix 6. The Station-Keeping Solar Sail Challenge - Draft Rules

Overview

The Station-Keeping Solar Sail Challenge is designed to promote the development of solar sail technology and the commercial services that may result from the ability to operate in novel orbits such as artificial Lagrange points.

The Station-Keeping Solar Sail Challenge has two prizes. To win Prize One and the \$2,500,000 purse, a Team must be the first to deploy a solar Sailcraft, demonstrate a resultant trajectory acceleration change of at least .05 millimeters per second squared, and fly along a trajectory that will pass through a defined target located at the first Sun-Earth Lagrange point (L1). To win Prize Two and the \$2,500,000 purse, a Team must enter a defined region above or below the ecliptic plane at L1 and remain there for 90 consecutive days.

Definitions

a. Advance Notification Information - In accordance with the Advance Notification Period Terms, Team will:

(1) Provide to Org all pertinent information regarding the Flight Attempt, including date, location, and mission profile.

(2) Provide to Org a detailed description (and possible demonstration) of their Sailcraft's safe design and operation.

(3) Notify Org of any known Flight Attempt delays at its earliest opportunity. If, in the opinion of Org, Team provides serial notices of delays for the purpose of gaining competitive advantage, the Team will be required to reinitiate the advance notification process.

b. Advance Notification Period Terms - At least 180 days prior to any Flight Attempt:

(1) Team must be officially registered and provide their intent to compete in the Challenge by providing design compliance and operational safety information to Org.

(2) Team will provide Org with all Advance Notification Information.

c. Baseline Trajectory – The trajectory “starting point” for the Sailcraft.

d. Challenge – The Station-Keeping Solar Sail Challenge.

e. Deadline - January 1, 2011 (local date and time in Washington, D.C., U.S.A.). The Deadline may be extended at the sole discretion of NASA.

f. Flight Attempt – Operation of the Sailcraft with the objective of meeting all the requirements for winning the Challenge.

g. Flight Attempt Information - All information regarding the Flight Attempt, including dates, times, and locations of take-off, and flight path.

h. Minimum Requirements – The Sailcraft:

(1) Shall not be attached to a kick motor or any other propulsive device at the time a Baseline Trajectory is declared.

(2) Shall be a free flying vehicle and not attached to another spacecraft at the time the competition attempt is performed.

(3) Shall have the ability to control the thrust vector.

(4) Shall have a radio transmitter capable of sending a signal that can be received by the Verification Site.

i. Org – The organization responsible for administering, executing, and judging the Challenge.

j. Proof of Sail Deployment – Evidence (e.g., images) that the Sailcraft was released from its packaging and achieved a state of deployment that would allow the transfer of momentum from sunlight. Teams not using imagery must have their strategy for proving sail deployment approved by Org before the Competition Attempt. Data supporting the deployment claim must be received at the Verification Site within one hour of the initiation of the acceleration change.

k. Region 1 – A region of space described by a circle whose center point is the Sun-Earth L1 Point, whose radius is perpendicular to the Sun-Earth Line, and whose radius is 650,000 kilometers.

l. Region 2 – A region of space at least 6 degrees north or south of the ecliptic at the Sun-Earth L1 point, and within 100,000 kilometers perpendicular to the sun-earth line in the ecliptic.

m. Sailcraft – The spacecraft that is device capable of transferring momentum from sunlight through the use of a solar sail and is entered by Team in the Challenge.

n. Validated Acceleration Change – A change in the acceleration of at least 0.05 millimeters per second squared from the Baseline Trajectory that has been accomplished solely by use of the solar sail. Validation will be accomplished through analysis of the Sailcraft's radio transmitter signal Doppler shift by the Verification Site.

o. Verification Site – To Be Determined.

Rules

- a. Technical specifications not already covered in this Agreement about the Sailcraft and any other Challenge details will be provided by Org to the Team at the time of registration. These technical specifications may be subject to future updates by Org at its discretion.
- b. Before the Competition Attempt, Team shall comply with the Advance Notification Period Terms.
- c. For the Competition Attempt, Team shall provide or make arrangements for the use of the Sailcraft and all the other necessary launch vehicles, facilities, equipment, personnel, etc., that will support and prove the performance of their Sailcraft.
- d. Team shall provide Proof of Sail Deployment.
- e. At a time after launch and before Proof of Sail Deployment, the Team shall notify the Verification Site that they wish to declare their Baseline Trajectory at a time that is mutually agreeable to the Team and the Verification Site. The Verification Site will provide the Team and Challenge officials with a Sailcraft position and trajectory within two hours of the Team's notification.
- f. The Sailcraft must meet all Minimum Requirements.
- g. The Team whose Sailcraft first performs actions (1) and (2) below in any order, within 30 days of launch, and before the Deadline will be awarded \$2,500,000 (two million five hundred thousand U.S. dollars).
- (1) Use a Sailcraft to achieve a Validated Acceleration Change.
- (2) Establish a trajectory that will pass through Region 1 with a Sailcraft.
- h. The Team whose Sailcraft first maintains position within Region 2 for 90 consecutive days will be awarded \$2,500,000 (two million five hundred thousand U.S. dollars).

Questions for Consideration by Respondent

- Are any of the definitions given missing, over-specifying, or incorrectly specifying important qualitative and quantitative parameters? (E.g., the maximum allowable mass is too low, etc.) If so, what should the proper parameter specification be and why?
- Are there any logistical or practical situations that have been overlooked? (E.g., considerations of safety, validation, operation of the competition event, etc.) If so, what situation has been overlooked and how should it be handled?
- Are there alternative ideas for conducting the competition, or scoring and awarding the prizes for the competition? If so, what are your proposed ideas and why?
- Is the prize purse adequately sized? Why or why not?
- What should be the size of the prize purse for accomplishing rule (g)?
- Should competitors be permitted to contract with government agencies for data sales or other services as long as no government funds have been received prior to launch (or

prize attempt)? For instance, several government agencies have expressed interest in receiving flight data. Such contracts may be constrained by the agencies' respective countries' laws e.g. Buy America Act.

- How does one verify the sail is actually causing the Sailcraft's acceleration and not some other propulsion system?
- Rule (d) currently states "The Verification Site will provide the Team and Challenge officials with a Sailcraft position and trajectory within two hours of the Team's notification." Is this time period sufficient?